Mounding to Improve Site Productivity: Growth and Survival

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submitted by

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Introduction

Mounding has been known to enhance site productivity on sites where productivity is limited by the amount of aerated soil available for rooting, and by slowly permeable soils. On Graham Island in the Queen Charlotte Islands, mounding is currently being used to improve site productivity where low relief and high precipitation relative to evapotranspiration combine to create shallow, perched water tables that limit the quality and quantity of available growing space for roots (Green 1996). Site productivity is not only determined by soil properties and other site features such as slope and aspect, it is also determined by climate which can have an over-riding impact on site productivity (Green 1989). Mounding attempts to create conditions that are more suitable for successful tree growth.

Mounding improves root zone soil drainage by increasing the volume of aerated soil, which enhances nutrient cycling that increase decomposition rates (Green 1996). Mounding also reduces mortality due to windthrow (Green 1989), by allowing root systems to occupy a greater volume of soil. Mounding also causes a mixing of organic and mineral horizons by disturbing soils, increasing decomposition rates (McColl and Powers 1984). Mounding caused by disturbance achieved naturally by blowdown or colluvial activity is associated with significantly improved tree growth within the study area (Green 1996). Mounding also has been used successfully in sub-boreal and boreal forest ecosystems where it has been found to improve the rate of regeneration and growth by raising soil temperatures and improving drainage (Haeussler 1989).

Without mounding to improve site productivity on poor sites, as forests age they eventually reach a point where demand for growing space and nutrients exceeds the supply capacity of soils that have shallow rooting zones. This leads to decline in height growth, dieback of root systems, opening of the canopy due to death of least tolerant species such as Sitka spruce (*Picea sitchensis)*, and invasion of understory shrubs like salal (*Gaultheria shallon*). Green (1996) found that Sitka spruce (Ss) in the Queen Charlotte Islands (QCI) showed the greatest sensitivity of all species to poor soil aeration and decreasing soil nutrient content. Mounding should enhance the growth of Ss, and

other species that share similar limitations for growth, on those sites having poor soil aeration and nutrient availability.

While Ss is sensitive to limiting site conditions, it can grow rapidly when site conditions become adequate for its requirements. On poorer sites, Ss is all but absent because of its inability to tolerating limiting site conditions (Green 1989). Western redcedar (*Thuja plicata*) has better adaptation to waterlogged soils, and the poorest of sites found in the QCI were dominated by western redcedar (Cw), followed by western hemlock (*Tsuga heterophylla*) (Green 1989). As a result, mature Cw – Hw stands predominate throughout this region and are more often found on poorly drained soils. The effects of poor soil aeration on tree growth also vary with the species, as different species have different capabilities for tolerating poor soil aeration. Cw has relatively high tolerance, and has morphological adaptations that give this tolerance.

Enhancement of site productivity by mounding has been achieved north of Port Clements, on the Queen Charlotte Islands. Green (1996; 1989) found that low (50cm), wide (2-3m) mounds offered good potential for improving long-term productivity. This is because modest increases in rooting depth are associated with substantial increases in tree growth; however, rooting depth is only one requirement as mounds must be wide in order for root systems to exploit the available soil as trees age and roots elongate. Green (1989) showed that effective rooting depth was associated with tree growth in the Graham Island study, where perched water tables and dense, heavy-textured, and/or strongly cemented soil layers limited total rooting depth. The site preparation and mounding were achieved on this site by using medium-sized excavators. This resulted in costs that were relatively high, but expected long-term gains could be substantial, in terms of stand yield and value, and in expanding the forest land base by including land currently excluded from the yield analysis (Green 1996).

Methods

Study Area

The experiment was established in the Submontane Wet Hypermaritime CWH biogeoclimatic variant (CWHwh1) at two locations north of Port Clements, Queen

Charlotte Islands (53°43′ N lat., 132°07′ W long.). Both sites occur on sand-textured outwash deposits that feature strongly cemented horizons (orstein and placic horizons) at approximately 30 cm from the ground surface. Thin (10-15 cm) silty textured eolian veneer overlays the outwash sands. The topography is very gently undulating to flat. These conditions create perched water tables over much of the area. The first area (Block 1) previously supported an overmature stand of Cw and Hw with a dense salal understory, while the second area (Block 2) supported a dense 150 year old stand of Cw, Hw, and Pl (*Pinus contorta v. latifolia*) with a predominantly moss understory and scattered salal cover. Block 1 features a moist to very moist soil moisture regime and poor soil nutrient regime, and mainly represents the CWHwh1/CwHw – Salal site series (Green and Klinka 1994). Block 2 features a moist to very moist soil moisture regime and poor to medium soil nutrient regime. It also represents the CWHwh1/CwHw – Salal site series, which characteristically lacks salal understory under dense second-growth stands. Both areas were logged in 1987 with no site preparation treatment.

Climate on the East side of Graham Island is relatively uniform and may be excluded as a factor contributing to productivity variation. While the shortage of soil water is not limiting, soil nutrients and soil oxygen are very important and appear to be influenced by the subdued physiography and soil physical properties such as fine-textured and compacted or cemented layers which limit soil drainage and rooting depth (Green 1989).

Design

A completely randomized design was used for the experiment. At each of two locations, all combinations of three site preparation and three tree species treatments were randomly assigned to 30m x 30m plots, with each treatment combination replicated in three plots. Forty subplots were systematically located within each plot (on mounds where treated), where trees were planted and subplot measurements made (Table 1). All treatment plots and subplots were marked with cedar stakes and numbered aluminum tags. The two experimental blocks were mapped at 1:5000 scale to facilitate remeasurement and demonstration (Green 1996).

Table 1. Summary of treatments and replications at each experimental block.

Treatment combination	Mounding treatment	Tree species	Number of plots	Number of subplots
1	Control	Ss	3	120
2	Control	Hw	3	120
3	Control	Cw	3	120
4	Mound	Ss	3	120
5	Mound	Hw	3	120
6	Mound	Cw	3	120
7	Mound and grass/legume	Ss	3	120
8	Mound and grass/legume	Hw	3	120
9	Mound and grass/legume	Cw	3	120
Total			27	1080

Treatments

Treatments consisted of a control, mound, and a mound/grass combination, created through site preparation, then planted with three tree species (Cw, Hw, and Ss) (Table 2). Of these species, only Sitka spruce (Ss) is normally not recommended for management in these ecosystems because of its high demands for a well-aerated rhizosphere. But because Ss has the potential for substantially improved performance on mounded microsites (Green 1996), it was included in the study.

Table 2. Summary of treatments and codes.

Treatment	Code
Site preparation	
Control	C
Mound	M
Mound and grass/legume	MG
Tree species	
Western redcedar	Cw
Sitka spruce	Ss
Western hemlock	Hw

Mounding treatments were completed in August 1989 using a RH09 60,000-lb excavator fitted with a regular bucket and thumb attachment. Mounds were created by lightly screefing the surface forest floor with one pass of the bucket, followed by depositing approximately 1.5 buckets of soil from an adjacent hole. The target of 40 evenly spaced, uniform mounds per plot was met (Green 1996). The mound/grass treatment consisted of mounds seeded with a grass/legume mixture applied in the spring of 1990 following planting of seedlings.

Plug stock seedlings were planted in the spring of 1990. Seedlings were protected from deer browsing with vexar tubing secured with one bamboo and one hooked metal stake. Unfortunately, high winds experienced in 1990/91 caused movement of the vexar causing extensive damage to seedlings. This damage resulted in high seedling mortality over the 1991 growing season. Vexar were removed from Hw and Ss seedlings in 1991 and vexar in the Cw treatments were re-secured with split Cw stakes and zap-straps. As a result of the high seedling mortality, a replanting was carried out in the spring of 1992 of all Cw in both blocks, all Hw in block 1, fill-in of dead Ss in both blocks and Hw in block 2 (Green 1996).

Tree Measurements

Measurements for growth and survival of seedling performance and condition were made immediately following planting in the fall of 1990 through to 1994 (refer to Green 1996 for data analysis). Measurements included total height, height increment, and caliper, with condition assessed according to several categories (Green 1996). Table 3 summarizes attributes and definitions used during remeasurement.

Table 3. Attributes used for seedling measurements.

Attribute	Code	Definition
Total height		Total height above ground (cm)
Height increment		Height increment (cm). Not measured in Cw.
Caliper		Stem caliper (mm) measured 10 cm above ground.
Vigour	0	dead
	1	moribund (unlikely to survive)
	2	poor
	3	moderate
	4	good (normal for healthy seedlings)
Foliar condition	1	healthy
	2	chlorotic (slight to moderate)
	3	chlorotic (moderate to severe)
	4	necrotic spots and bands
	5	poor needle retention
Damage	0	none
	1	browsed leader
	2	frost heaving
	3	exposed plug from soil erosion
	4	loose plug from wind rocking
	5	leader dieback
	6	lateral dieback
	7	late season flush
	8	broken stem
	9	stem sweep or bend
	10	forked leader
	12	forked stem

Remeasurements for 1997 included height, caliper, height increment (except Cw), vigour, foliar condition, and damage. Tree heights were taken from the point of germination to the top of the leader; any effect that frost heaving may have had on heights was not counted. Leaders were measured to include the whole length of the leader. Hw leaders were estimated whenever the leader was bent over and when the height of the tree prevented the leader from being straightened. Caliper was measured at 10 cm. If a fork or deformity prevented measurement at 10 cm, the measurement was taken immediately above the fork or deformity. Height increment was measured between branch nodes (in cm). The standards for height measurement and caliper were +/- 3 cm and +/- 2 mm respectively (Courtin, 1997).

Damage code "3" was used to indicate a situation where a mound was eroding and roots were now exposed. Tags for block 1 were used to replace worn blue plastic discs and missing metal tags. Tags were tied to stakes unless trees were large enough to attach tags to the branches of the tree. In block 2, all Hw and Ss were tagged. If trees were too small to be tagged, tags were attached to stakes. All tags were attached to the southwest side of trees at breast height.

In September 1997, an eight year remeasurement of all Ss and Hw in block 2 and all Ss in block 1, and a six year remeasurement of all Cw and Hw in block 1 and Cw in block 2 was completed.

Data Analysis

Data was used from Green (1996) and was compared with data collected in September 1997. Statistical analyses were conducted on height, caliper, and increment for each species between each treatment and within each block using a single factor ANOVA for uneven sample sizes (Plamondon, 1997). If significance was detected, a pooled variance Student's t-Test was conducted to find where significance in measurements was located (Moore and McCabe, 1989). Because of the variability between both blocks 1 and 2 (eg. age difference), an ANOVA was not used to test for between site differences. Data compilation was completed using Excel for Windows

Version 5. All data was statistically analyzed using SPSS for Windows Version 8 and Excel for Windows Version 5.

Results

Similar to Green (1996) the approach to data analysis was strongly influenced by the seedling replanting undertaken in 1992. As a result, data analysis followed Green (1996) where data were analyzed separately by species within each block. This report analyzed data for Cw and Hw at the 6-year interval, while Ss were analyzed at the 8-year interval.

Growth

Tables 4 and 5 show mean height data from 1994 and 1997 respectively. The accompanying graphs can be seen in Figures 1, 2, and 3. Height growth (Figure 1) for Cw

Table 4. 1994 total height (cm) by species and treatment for blocks 1 and 2 (Green 1996).

Treatment (by block)	Species Cw[1]			Hw[2]			Ss[3]		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Block 1									
C	88	41	20	32	27	15	97	45	20
M	112	49	19	85	50	21	101	84	40
M G	118	37	14	105	48	21	111	101	31
Block 2									
C	118	79	31	97	192	89	109	166	65
M	119	76	35	99	159	67	108	139	63
M G	120	61	18	100	196	73	115	154	62

[1]Cw replanted spring 1992 in Blocks 1 and 2.

[2]Hw planted spring 1990 in Block 2; replanted spring 1992 in Block 1.

[3]Ss planted spring 1990 in Blocks 1 and 2.

Table 5. 1997 total height (cm) by species and treatment for blocks 1 and 2.

Treatment (by block)	Species Cw[1]			Hw[2]			Ss[3]		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Block 1									
C	60	69.3	29.5	29	41.4	19.0	109	58.3	29.9
M	114	77.5	32.2	84	62.4	28.2	115	117.9	71.8
M G	120	61.7	26.0	112	61.5	27.2	116	131.8	55.7
Block 2									
C	117	138.8	50.5	106	266.0	134.4	118	252.7	102.2
M	119	139.3	57.6	113	230.2	114.5	120	253.4	106.3

M G	120	130.4	34.0	113	279.9	131.5	116	259.7	89.6

[1]Cw replanted spring 1992 in Blocks 1 and 2.

[2]Hw planted spring 1990 in Block 2; replanted spring 1992 in Block 1.

[3]Ss planted spring 1990 in Blocks 1 and 2.

in block 1 over the four-year period appears to have increased at the same rate in each of the three treatments, with best growth occurring in the mound treatment. Growth for Hw (Figure 2) in block 1 for the same four year period is similar for the mound and mound/grass treatment, while growth in the control was lowest. Ss (Figure 3) in both the mound and mound/grass treatments show good growth at similar rates, while Ss in the control has a much lower total height and a slower rate of growth.

Figures 4, 5, and 6 show height growth rates as above but represent growth for block 2. Height growth for Cw (Figure 4) shows a high rate of growth across all three treatments. Growth for Hw (Figure 5) shows good rates of growth in all three treatments, but growth was lowest for the mound treatment compared to the control and mound/grass. Figure 6 represents growth for Ss in block 2. All three treatments show very good rates of growth for the four-year period.

Tables 6 through 9 represents Analysis of variance (ANOVA) and *F*-tests conducted on height data within each of three species and two blocks. Significant differences were detected in block 1 Cw, Hw, and Ss, while significance was detected in Hw heights in block 2 only. The Students t-Test result, as seen in Table 14, shows that significant differences in height was found between the mound/mound-grass treatments of Cw, the control/mound and control/mound-grass treatments of Hw, and the control/mound and control/mound-grass treatments of Ss. For block 2, significance was detected for height in Hw only, and was found to be between the mound/mound-grass treatments.

Caliper measurements for the three species in each treatment in blocks 1 and 2 for 1997 can be seen in Table 14. Caliper growth was highest for the mound treatment in both Cw and Hw in block 1, and caliper was highest for the mound-grass treatment in Ss in block 1. Caliper growth was highest in the control treatment for Cw and in the mound treatment for Hw and Ss in block 2. The ANOVA and *F*-tests for caliper in both blocks 1 and 2 are seen in Tables 10 through 13. Significance was detected in block 1 Cw, Hw, and Ss, while significance was detected in Ss in block 2 only. Results from the Students t-Test (Table 14) show that significant differences in caliper occurred between the control/mound and control/mound-grass for Cw, the control/mound and control/mound-

Table 6. Analysis of variance on Cw height within block 1 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	14542.57	7271.29	8.55	0.05	3.00
Within Groups	291	247513.40	850.56			
Total	293	262055.90				

Table 7. Analysis of variance on Hw height within block 1 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	10690.44	5345.22	7.50	0.05	3.00
Within Groups	222	158297.60	713.05			
Total	224	168988.00				

Table 8. Analysis of variance on Ss height within block 1 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	339131.60	169565.80	54.88	0.05	3.00
Within Groups	337	1041263.00	3089.80			
Total	339	1380394.00				

Table 9. Analysis of variance on Hw height within block 2 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	147712.10	73856.06	4.59	0.05	3.00
Within Groups	327	5264366.00	16098.98			
Total	329	5412078.00				

Table 10. Analysis of variance on Cw caliper within block 1 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	623.50	311.75	22.76	0.05	3.00
Within Groups	291	3985.98	13.70			
Total	293	4609.49				

Table 11. Analysis of variance on Hw caliper within block 1 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	551.56	275.78	10.11	0.05	3.00
Within Groups	222	6054.98	27.27			
Total	224	6606.54				

Table 12. Analysis of variance on Ss caliper within block 1 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	34684.59	17342.30	65.77	0.05	3.00
Within Groups	337	88858.90	263.68			
Total	339	123543.50				

Table 13. Analysis of variance on Ss caliper within block 2 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	10372.26	5186.13	6.36	0.05	3.00
Within Groups	351	286337.20	815.78			
Total	353	296709.40				

Table 14. Mean height, caliper, and increment for blocks 1 and 2 mounding treatments. Means connected by the same vertical bar (or above or below the bar), to the right of their column, are not significantly different (P=0.05).

Location	Species	Treatment	Mean Height (m)	Mean Caliper (cm)	Mean Increment (cm)
Block 1	Cw	Control	69.292	6.25	n/a
		Mound	77.513	9.697	n/a
		Mound/Grass	61.742	7.025	n/a
	Hw	Control	41.345	4.400	6.259
		Mound	62.369	9.446	6.548
		Mound/Grass	61.518	8.330	6.795
	Ss	Control	58.294	12.794	7.220
		Mound	117.861	34.183	14.287
		Mound/Grass	131.763	34.677	11.375
Block 2	Cw	Control	138.855	19.709	n/a
		Mound	139.319	18.487	n/a
		Mound/Grass	130.338	17.200	n/a
	Hw	Control	266.053	55.082	26.106
		Mound	230.252	62.438	25.106
		Mound/Grass	279.872	59.527	32.982
	Ss	Control	252.270	57.932	24.504
		Mound	253.346	71.114	34.200
		Mound/Grass	259.668	63.918	26.336

grass for Hw, and in the control/mound and control/mound-grass for the Ss in block 1. For block 2, significant differences in caliper were detected for the control/mound of Ss.

Increment was measured for Hw and Ss and is seen in Table 14. Increment growth was highest in the mound-grass treatment for Hw and the Ss in block 1, and

increment was highest for mound-grass in both Hw and Ss in block 2. The ANOVA and *F*-tests for increment in both blocks 1 and 2 are seen Tables 15 and 16. Significance was detected in the Ss in block 1 and block 2 only. Results from the Students t-Test (Table 14) show that significant differences in increment were found between the control/mound and control/mound-grass for Ss in block 1. For block 2, significance was found between the control/mound and mound/mound-grass for Ss.

Table 15. Analysis of variance on Ss increment within block 1 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	2815.80	1407.90	9.35	0.05	3.00
Within Groups	337	50747.90	150.59			
Total	339	53563.70				

Table 16. Analysis of variance on Ss increment within block 2 mounding trials.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2	6321.73	3160.86	8.55	0.05	3.00
Within Groups	351	129769.80	369.71			
Total	353	136091.60				

Green (1996) also found significant differences in growth between both blocks. Growth in block 1 was consistently poorer than in block 2, especially in both the control and mound treatments. After the 1997 remeasurements, the data are similar to that collected in 1994; that is, growth is lower in block 1 than in block 2, and growth is still occurring at a faster rate in block 2 than in block 1. The ecological difference between both blocks becomes apparent upon examination of the data. Block 1 is salal-dominated which appears to have a profound effect on soil nutrition, as tree performance is significantly different on mineral soil mounds that lacked salal cover (Green 1996). Because both sites share similar soil parent materials, salal dominance in block 1 may be having competitive influence on Cw, Hw, and Ss for nutrients and light, resulting in reduced growth for all trees. Still, because of the poorer site quality of block 1, growth rates should be lower when compared to block 2.

A positive effect on growth comes directly from the mounding treatments. The impact of mounding varies with species and block. Because block 1 is a poorer quality site, positive effects due to mounding were more pronounced (Green 1996), and this trend has continued into 1997. Hw and Ss appears to do well in both the mound and mound-grass treatments than in the control in block 1. Green (1996) speculated that Hw did poorly in the control because of stock quality or handling problems during the replant. Ss, on the other hand, did poorly in the control because of the lower site productivity because nutrients required for growth of Ss in the control in block 1 may be limiting. Cw shows poorer performance in the mound-grass treatments in block 1. Cw seedlings may have been from stock having morphological adaptations to high water tables and poor soil aeration; therefore, the mound-grass treatment may not be conducive to good Cw growth. Green (1996) also found poorer performance in Cw and concluded that it reflected the competitive influence of the grass.

Survival

Table 17 shows tree condition by species and treatment for each of blocks 1 and 2 for 1994. Table 18 shows tree condition by species and treatment for each of blocks 1 and

Table 17. 1994 tree condition by species and treatment for blocks 1 and 2 (Green 1996).

Condition (by block)	Species Cw[1]			Hw[2]			Ss[3]		
	C	M	M G	C	M	M G	C	M	M G
Block 1									
Survival	73	93	98	27	71	99	92	84	92
Slight-mod. chlorosis	40	29	31	34	54	51	42	46	52
Mod-severe chlorosis	35	47	49	3	18	31	8	10	5
Browsed leader	10	1	4	0	0	0	7	10	14
Dieback of leader	9	3	1	69	45	32	19	6	5
Exposed plug	0	0	0	3	1	1	0	62	8
Block 2									
Survival	98	99	100	85	82	83	91	90	97
Slight-mod. chlorosis	63	37	57	31	54	41	18	17	23
Mod-severe chlorosis	25	38	31	12	10	8	1	3	7
Browsed leader	33	39	38	0	1	0	8	8	12
Dieback of leader	0	0	0	10	8	12	10	11	7
Exposed plug	0	2	0	0	55	15	0	31	5

[1]Cw replanted spring 1992 in Blocks 1 and 2.

[2]Hw planted spring 1990 in Block 2; replanted spring 1992 in Block 1.

[3]Ss planted spring 1990 in Blocks 1 and 2.

and 2 for 1997. Survival of Cw in block 1 controls has declined since 1994, while all

Table 18. 1997 tree condition by species and treatment for blocks 1 and 2.

Condition (by block)	Species Cw[1]			Hw[2]			Ss[3]		
	C	M	M G	C	M	M G	C	M	M G
Block 1									
Survival	60	113	120	29	84	112	109	115	115
Unlikely to survive	3	2	7	2	3	1	4	3	5
Slight-mod. Chlorosis	7	23	43	12	33	71	53	38	55
Mod-severe chlorosis	4	13	14	1	31	29	16	33	19
Necrotic spots and bands	1	1	8	0	0	1	1	1	2
Poor needle retention	1	0	2	0	7	0	4	9	14
Browsed leader	1	5	1	0	0	1	8	1	3
Frost heaving	0	5	0	0	3	1	0	23	1
Exposed plug: soil erosion	0	1	1	0	0	0	0	6	0
Loose plug: wind rocking	0	0	0	0	0	1	0	0	1
Leader dieback	0	6	3	6	11	16	7	5	2
Lateral dieback	0	1	3	0	9	3	2	2	2
Broken stem	1	1	1	0	0	0	11	5	1
Stem sweep or bend	3	13	10	0	2	1	9	15	22
Forked leader	0	5	1	0	2	6	7	5	2
Forked stem	7	17	7	20	64	86	11	18	17
Smothered by vegetation	1	0	0	2	1	1	1	0	0
Block 2									
Survival	117	119	120	104	113	113	118	120	114
Unlikely to survive	0	0	0	0	0	0	0	1	0
Slight-mod. Chlorosis	3	8	3	22	43	28	27	18	20
Mod-severe chlorosis	0	1	0	1	12	2	2	0	2
Necrotic spots and bands	3	2	1	0	0	0	18	10	16
Poor needle retention	0	0	0	0	0	0	3	0	1
Browsed leader	29	16	20	2	0	1	5	2	0
Frost heaving	0	0	0	0	10	0	1	6	1
Exposed plug: soil erosion	0	0	0	0	3	0	0	3	1
Loose plug: wind rocking	0	0	0	0	0	0	1	2	1
Leader dieback	1	0	3	5	3	3	3	3	1
Lateral dieback	1	0	0	0	2	1	0	0	0
Late season flush	0	0	0	0	0	0	0	1	0
Broken stem	0	0	0	1	1	2	10	10	3
Stem sweep or bend	6	6	11	10	8	5	17	19	8
Forked leader	2	2	1	5	3	5	2	9	3
Forked stem	13	13	18	27	62	38	23	51	25
Smothered by vegetation	3	2	0	0	0	0	0	0	0

[1]Cw replanted spring 1992 in Blocks 1 and 2.

[2]Hw planted spring 1990 in Block 2; replanted spring 1992 in Block 1.

[3]Ss planted spring 1990 in Blocks 1 and 2.

other treatments and all three species have shown increased survival since 1994. Many trees of all three species, with the exception of Cw and Hw block 1 controls, were found to have relatively high frequencies of slight to moderate and moderate to severe chlorosis. Block 2 had the highest survival compared to block 1. Only Hw and Ss in all three treatments of block 2 had high numbers of trees with slight to moderate chlorosis; this has

changed little since the last measurement in 1994. The higher incidence of slight to moderate and moderate to severe chlorosis in block 1 than block 2 reflects the poorer quality of the block 1 site.

Hw in block 1 had high incidence of forked stems in all three treatments compared to other species and treatments. Again, as in block 1, Hw in block 2 had a higher incidence of forked stems than Cw and Ss, and Ss had a high number of forked stems in

the mound treatments. Green (1996) found that Ss in the mounding treatments had stem damage due to abrasion from the vexar, and may account for the high incidence of forked stems in Hw. Vexar abrasion may also account for the poorer response in block 2 mounds, especially on Hw and Ss growth. Cw in block 2 for all three treatments had a higher number of browsed leaders compared to Hw and Ss. This shows that Cw is the species most preferred by deer. There were fewer browsed Cw in block 1 which may have been the result of lower foliar nutrient content or lower visibility due to salal cover (Green 1996).

Survival of each species within each treatment in both blocks 1 and 2 are shown in Figures 7 – 12. Cw in block 1 (Figure 7), as well as Hw in block 1 (Figure 8) had the lowest survival in the control subplots. The Ss in block 1 (Figure 9) had a high increase in survival since 1994. An increase in survival is due to replanted Ss not being included in the analysis from Green (1996). In the four years since the last remeasurement, Cw, Hw and Ss in block 2 (Figure 10, 11, and 12) have survived quite well in all of the treatments. Again, this is reflected in the better quality of the site compared to block 1.

There is a noticeable difference in site quality between blocks 1 and 2 upon examination of the data. The mounding treatments of block 1 show a consistent and lower growth rate when compared to the mounding treatments of block 2, where growth rates are steadily increasing over time. The untreated controls of block 1 show a lower rate of growth than the treated plots of block 2. Because of high water tables, and compacted and cemented soil horizons, growth will continue to be lower in the control than in the mounded treatments. As Green (1996) found, the effects of mounding treatments may take longer to be fully expressed, and the critical point will be when

rooting networks begin to occupy the larger volume of soil, and therefore the increased aeration and nutrients, available from the mounds.

References

Courtin, P. J. 1997. Pers. Comm.

Green, R.N. 1989. Site-forest productivity relationships and their management implications in coastal lowland ecosystems of east Graham Island, Queen Charlotte Islands. M.Sc. thesis, Dept. of Forestry, Univ. of B.C., Vancouver, B.C.

_____1996. Mounding to improve site productivity. SMFRA Project 15.1, Queen Charlotte Islands, 1995 Progress Report.

Green, R.N. and K. Klinka. 1994. A field guide to site identification and interpretation f or the Vancouver Forest Region. B.C. Min. For., Land Management Handbook No. 28, Victoria, B.C.

McColl, J.G. and R.F. Powers. 1984. Consequences of forest management on soil-tree relationships. *In* G.D. Bowen and E.K.S. Nambiar (eds.). Nutrition of plantation forests. Academic Press, London.

Moore, D.S., and G.P. McCabe. 1989. Introduction to the Practice of Statistics. W.H. Freeman and Company, New York.

Plamondon, J.L. 1997. Stem growth, branch angle, and branch number as affected by stand density and site productivity in young red alder (*Alnus rubra* Bong.) spacing trials on Vancouver Island. Undergraduate Research, Simon Fraser University, Burnaby, B.C.